Large-area Silicon Masters for the Fabrication of Nanostructured Bioactive Surfaces utilizing Laser Interference Nanolithography and Dry Etching.

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Enhancing bioactivity and osteoconductivity of biomaterials by applying a nanostructured surface is widely studied in the biomaterial sciences. Here we communicate an approach that is based on nanostructuring biomaterials with large area (> 4 cm^2) in order to get reliable qualitative and quantitative data of the cell response. Silicon nanomachining technology and replication was utilized to obtain highly-regular nanopatterned surfaces for biological evaluation. The nanomachining process includes: Laser Interference Lithography applying both positive and negative resist and Reactive Ion Etching to generate a large area nanopatterned silicon master. Subsequently the master is reproduced multiple times to obtain substrates for cell culturing. We optimized the nanopattern transfer process for both aspect-ratios, the line width-to-pitch and the line width-to-height, respectively by tuning the RIE process by selecting the machine as well as specific process conditions. Figure 1 A to E show the results achieved by standard parallel plate process using SF_6 plasma chemistry while the figures F and G were obtained using cryogenic DRIE process yielding in lateral sizes starting from 70 up to 500 nm and a height aspect ratio of up to 4:1.

Cell-surface interactions on patterned surfaces are mainly driven by geometrical effects and less by material properties [1]. Initial *in vitro* studies with connective tissue cells performed on the nanostructures, fabricated utilizing the technology described above, are presented in figure 2. To acquire the maximum amount of information concerning the influence of surface topology on cell-surface interaction, it is essential to choose a pattern of lowest symmetry order, i.e. ridges were fabricated here. Also other nanoarray configurations are possible, like pillars and wells. The nanopatterned masters can be further employed for patterning other materials, like polymers or metals used in biomaterial applications.

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[2] Frank Walboomers, Dedicated nanometric surface topography and bone cell behavior, Invited oral at E-MRS Fall Meeting 2008, Warsaw.
[3] R. Luttge, H. A. G. M. van Wolferen, and L. Abelmann, Journal of Vacuum Science & Technology B 25, 2476 (2007).

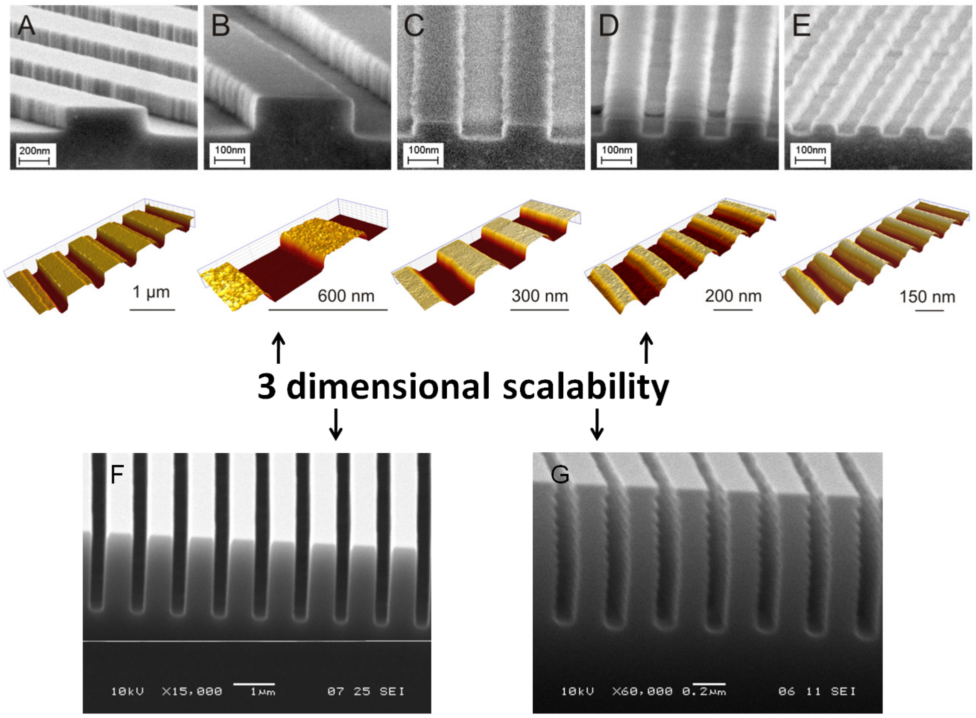

Figure 1. Scanning Electron Micrography and Atomic Force Microscopy study of features in nanomachined silicon. The lateral sizes of structures are in the range of sub micrometers with smallest features down to 70 nm. A,B,C,D,E – different periods (pitch) emerging from the configuration of the LIL setup (angle of incidence) and subsequent RIE (PlasmaTherm 790, Uniaxis) [2].F, G -Deep reactive ion etching of the nanostructures is giving a possibility to create structures with higher aspect ratios. (Adixen SE, Alcatel). Positive polyvinyl based resist PEK500 (Sumitomo Chemical) or negative MA-N2403 (Microresist) were used in the study.

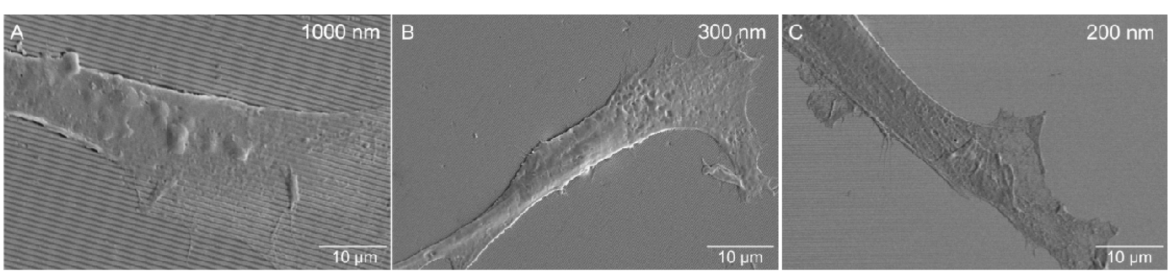

Figure 2. Fibroblasts cultured on patterned polystyrene with nanostructures obtained from silicon master replication.